Rainy seasonal analysis of Physico-chemical parameters of Mukungwa River at NGARU point

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Abstract**—** *Water availability and quality are important factors that determine not only where people can live, but also the quality of life. The Mukungwa river is affected by rainy season especially at Ngaru point before discharge in Nyabarongo river, where its physico – chemical properties are seasonally changed. This may cause serious problems on all forms of life in the river. Objective of this work was to assess the impacts of rainy season on physico-chemical properties of Mukugwa River before discharging into Nyabarongo River at Ngaru. The parameters such as pH, temperature, turbidity, electric conductivity, total dissolved solids (TSS), phosphates, nitrates, and ammonium were monitored in three rainy seasons: April, 2012; October, 2012 and May, 2017 respectively. In this research, pH, temperature, electric conductivity were analyzed in situ using multifunction pH-meter and others parameters, were analyzed in laboratory using electrometric, volumetric, turbidity tube and colorimetric methods. The measured values for each parameter in three seasons were analyzed using MS Excel, and then compared to their international standards for surface water delivered by World Health Organization (WHO). The findings showed high variation of TSS (134mg/l, 178mg/l, and 582mg/l), turbidity (322NTU, 317NTU and 1560NTU) and ammonium (0.498mg/L, 0.536mg/L and 0.78mg/L) in three rainy seasons assessed. The quality of Mukungwa River needs prevention measures in order to control its pollution by erosion.*

***Keywords—* physico-chemical parameters, seasonal analysis, water quality, water pollution.**

I. INTRODUCTION

Surface waters include lakes, rivers, streams and reservoirs (Meybeck & Helmer, 1996). Physical, chemical measurements can be used together to describe the overall quality or health of aquatic ecosystems. Many factors influence water quality including climate and precipitation, soil type, geology, vegetation, groundwater and flow conditions as well as human activities (Sahuquillo, 2017).

The availability and quality of water always played an important part in determining not only where people can live, but also quality of life (Weaver, Granato, & Fitzgerald, 2019). Water is needed for agricultural, pastoral and industrial as well as for human consumption both in rural and urban areas, for socio-economic development purposes. It is used as a source of hydroelectric energy and for river and lake transport (Michel, 1993)**.** All these forms of use have often harmful consequences on water resources which are often characterized by physical, chemical and biological disturbances (Castree, 2006).

Rivers are like roads carrying water, organisms and important gases and nutrients to many areas. They help drain rainwater and provide habitats for many species such plants and animals (Michel, 1993)**.** Aquatic environmental chemical phenomena involve chemical processes, including acid-base, solubility, oxidation-reduction, and complexation reactions. The chemistry of rivers is complex and depends on inputs from the atmosphere, the geology through which it travels and the inputs from man's activities (Manahan, 2000).

According to (KABALISA et al., 2005), Water pollution in Rwanda is mainly coming from domestic waste, agro-pastoral and industrial activities. In Rwanda water resources are very important for sustainable development. Hence the Rwanda Government puts high priority in monitoring the quantity and the quality of the water resources in the country (KABALISA et al., 2005).

Based on the field observation, the selected study area is densely populated and mountainous which resulted in serious problem of erosion in the rain season. The crops such as rice, bananas, and beans were the most agriculture forms applied around the river. Through erosion, soil, organic materials, plant nutrients from agriculture, micro-biological pollution from domestic wastes and destruction of latrines at home, may change the quality of Mukungwa river water at this site. This may lead to the contamination of aquatic biota in the River as well as human health. That is why physico – chemical analyses have been conducted, to assess the impacts of rainy seasons on the quality of natural water resources in Rwanda especially in Mukungwa river at Ngaru point.

The Mukungwa River water quality is affected by chemical pollution from human activities around the River. This research has been conducted on Mukungwa River; to analyze the change of physical and chemical parameters in rainy seasons before discharging in Nyabarongo River at Ngaru. The main cause of water pollution will be identified and its impact on environment, then formulate recommendations.

II. MATERIAL AND METHODS

2.1 Study area description

The NGARU is a point where Mukungwa River discharges in Nyabarongo River. It is located in the region where Gakenke (in Northern Province), Ngororero (in Western province) and Muhanga (Southern province) districts meets together. The geographical coordinates of this site are: X 0461726 (longitude) and Y 9808506 (latitude), S 01. 43 .927 (south) and E 029 .39 .362 (East).

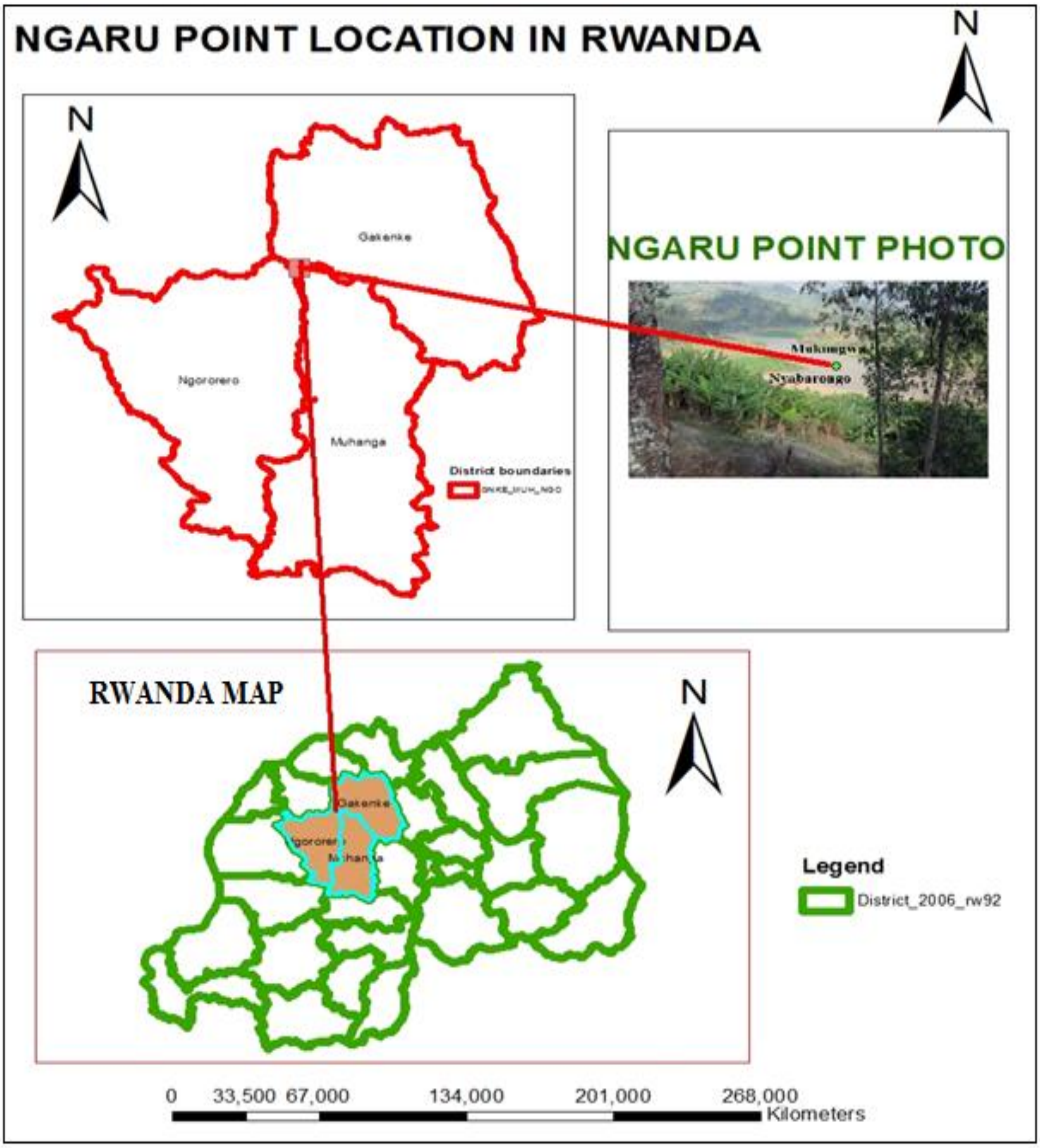


FIGURE 1: Sampling Site Location of NGARU point

2.2 Sampling techniques

Samples were taken in Mukungwa River before discharging in Nyabarongo River at Ngaru in the rainy seasons of April, 2012; October, 2012 and May, 2017. Samples for chemical parameters (Phosphates, nitrates and ammonium), total suspended solids (TSS) and turbidity were collected from the River at 20cm depth, using sterilized polyethylene bottles and kept in cool environment before laboratory analyses to prevent their deterioration. Physical parameters (temperature and electrical conductivity, EC) and pH were immediately in situ analyzed using multifunction pH-meter (pH – meter WTW pH 340i/SET Model).

2.3 Laboratory analytical techniques

2.3.1 Turbidity analysis

Turbidity was measured using turbidity tube method using nephelometer which is based on the visual interpretation of the turbidity of water. The visual appearance of black cross mark at the bottom of the tube, through the open end is used for turbidity measurement. A well-mixed sample was poured into the cleaned turbidity tube that was placed above the white sheet placed on the floor. The open end of the tube was observed to visualize the black markings from the distance of 7 to 10cm. The level of water, at which the black mark was seen, was noted down and reported in Nephelometric Turbidity Units (NTU).

2.3.2 Phosphates (PO_4^{3}-) analysis

Phosphates were measured using phosphate reagent (phosphaVer 3) which is a mixing of potassium thiosulphate ($K_2S_2O_8$), ascorbic acid and molybdenum oxide. Phosphates ions react with molybdenum oxide to form a yellow complex, phosphomolybdic which will react with ascorbic acid to generate the blue colored pieces of Molybdenum and titrate them by colorimetric method.

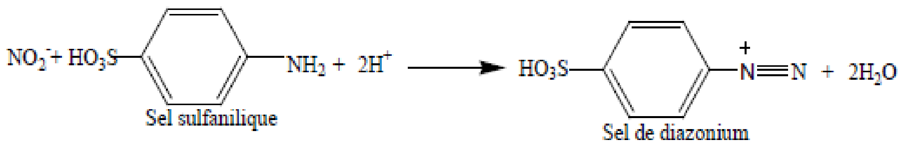
2.3.3 Nitrates (NO_3^-) analysis

Nitrates were analyzed by Cadmium reduction method using spectrophotometer of UV visible. The reagent is nitraVer which is mixture of cadmium and sulfanilic acid; where Cd reduces nitrates to nitrites.

$$NO_3^- + Cd + 2H^+ \rightarrow NO_2^- + Cd^{2+} + H_2O \quad (1)$$

Sulfanilic acid reacts with nitrite to give an intermediate diazonium salts. The later react with genticic acid to produce a highly coloured (gray) complex which intensity of coloration is proportionally to the concentration of the available nitrates ion in the sample.

The reactions involved are:



(2)

2.3.4 Ammonium (NH_4^+) analysis

The concentration of ammonium has been determined colorimetrically using Nessler method in which potassium, mercury, and iodine react with ammonium (NH_4^+) to create a yellow-brownish colored compound. The color intensity of the final compound is proportional to the concentration of target of ammonium (NH_4^+) in target samples.

2.3.5 Total suspended solids (TSS) analysis

The concentration of total suspended solids (TSS) was determined according to Standard methods 2540 D by filtering a defined water volume through a membrane filter (cellulose nitrate 0.45mm) and weighing the dried residues.

2.3.6 Statistical analysis of measured data

Having data for all parameters, measured in three rainy seasons, they have been statistically compared each other and with their accepted international standards values for surface water, delivered by World Health Organization (WHO) using MS Excel.

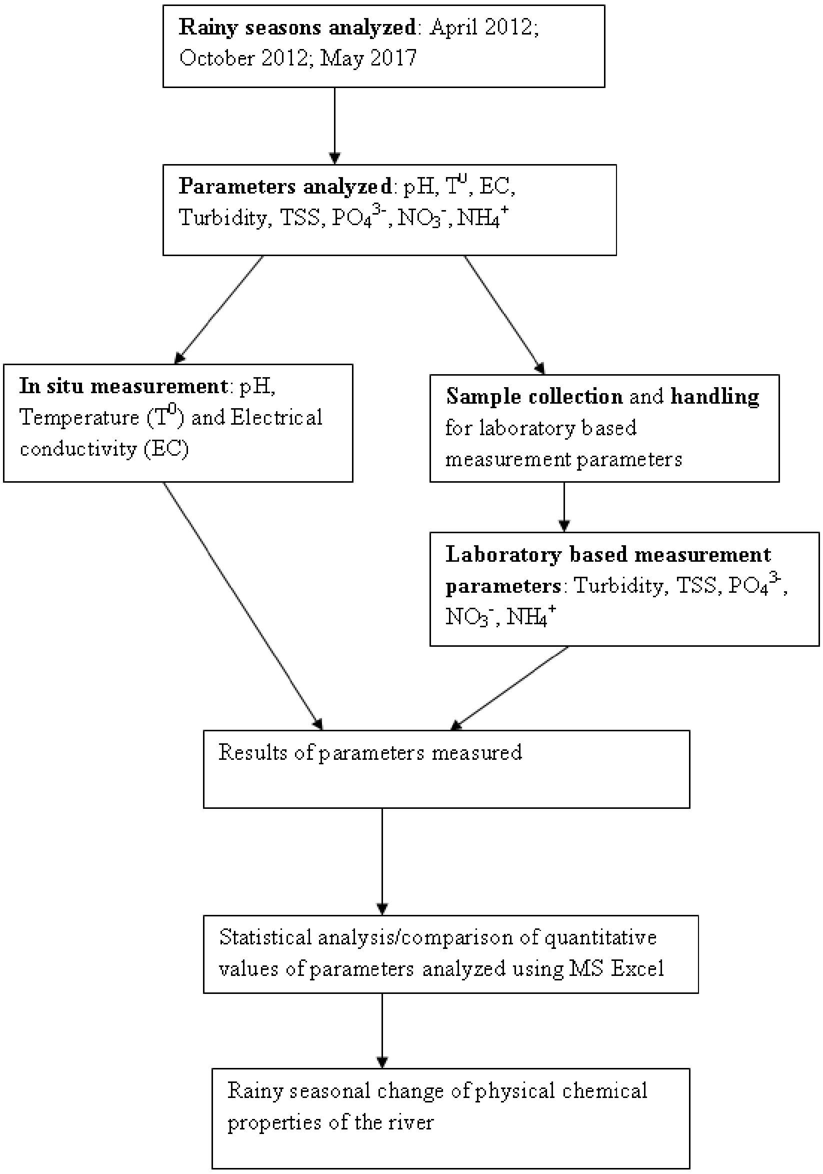


FIGURE 2. Methodological flow chart

III. RESULTS PRESENTATION

3.1 Results

TABLE 1
RESULTS OF PHYSICAL CHEMICAL PARAMETERS ANALYZED, OF MUKUNGWA RIVER BEFORE GETTING INTO NYABARONGO RIVER AT NGARU

Parameter	TEMP (^oC)	pH	E.C (µS/cm)	Turbidity (NTU)	TSS (mg/l)	NITRATES-N(mg/l)	Ammonia-N(mg/l)	PHOSPHSTE (mg/l)
April,2012	20,9	8.1	551	322	134	0	0.989	0.093
Oct,2012	22.4	7.92	153.1	317	178	2.012	0.536	0.444
May,2017	20.16	8.16	216.5	1560	582	1.159	0.678	0.519
WHO's accepted value	**Ambient**	**6.5-8.5**	**<1000**	**<5**	**<30**	**<10**	**<0.5**	**<5**

3.2 Interpretation of Results

3.2.1 pH and Temperature

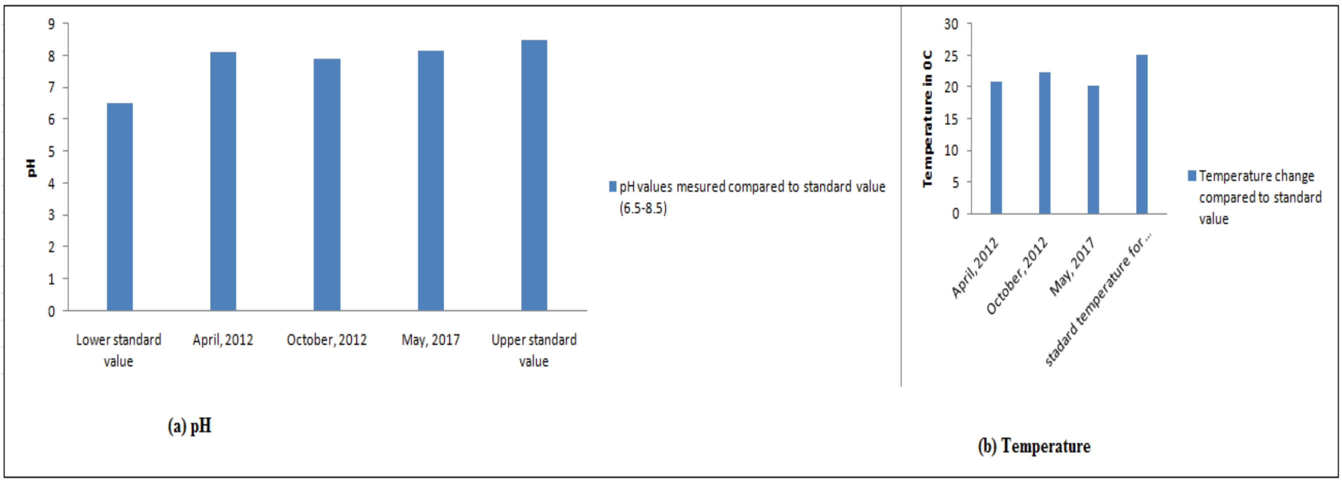


FIGURE 3. (a) pH Variation (b) Temperature change (^{0}C)

The pH is an important parameter which is important in evaluating the acid-base balance of water (REMA, 2010). The results obtained, the pH of Mukungwa in three rainy seasons is in alkaline range and is also found in acceptable range of standard for surface water (pH6.5-8.5). Thus, the trend of pH of Mukungwa River does not show a great change that falls out of the range of acceptable standard. Therefore Mukungwa has not been affected by rainy seasons in that period of time and is compatible for the requirements of the water norms for the protection of the aquatic life.

In the same way, temperature is one of the main physical properties affecting aquatic life. Very low water temperatures result in very slow biological processes, whereas very high temperatures are fatal to most organisms (Poff, Brinson, & John W. Day, 2002). The variation of temperature value of Mukungwa River observed in these three seasons is less than the standard temperature for surface water (ambient temperature 25^{0}C) and also, is not too low. So the rainy season did not affect the temperature of Mukungwa too much such that it can affect the aquatic environment. Thus Mukungwa water is acceptable for aquatic life.

3.2.2 Turbidity, Electrical Conductivity and Total suspended solids (TSS)

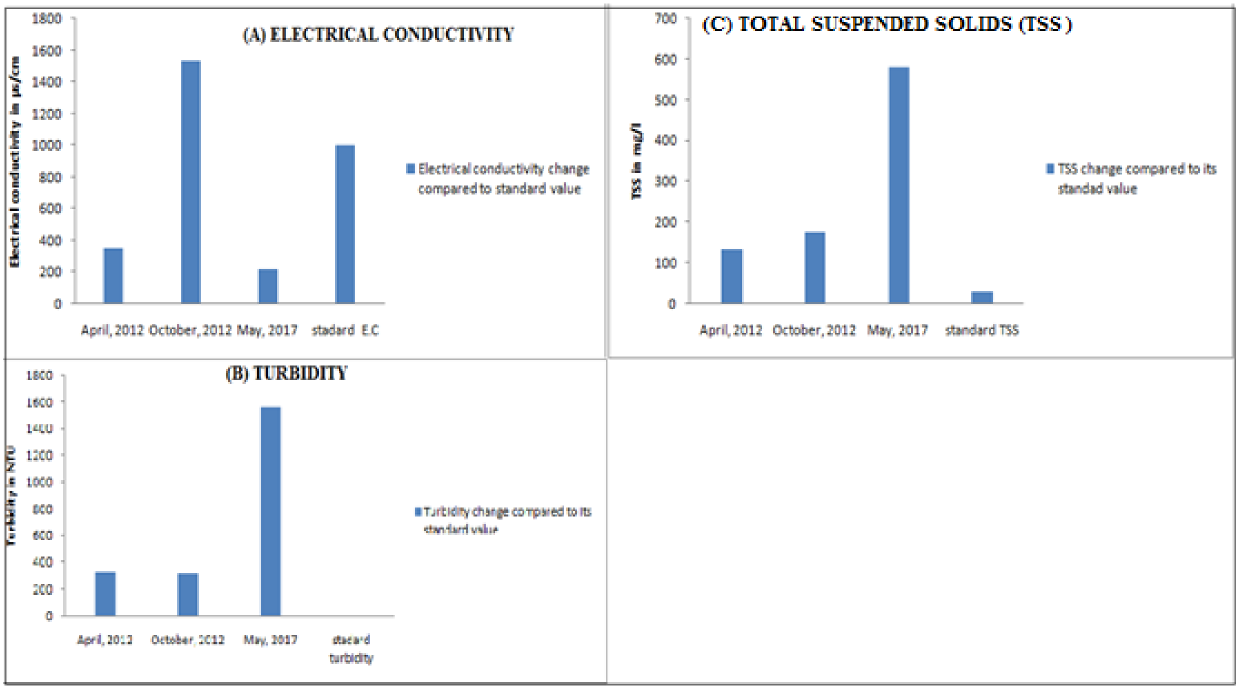


FIGURE. 4. Variation of turbidity, electrical conductivity and Total suspended solids in Mukungwa river.

Electrical conductivity measurement is an excellent indicator of total dissolved solids (TDS), which is a measure of salinity that affects the taste of water (Freber et al., 2004). The electrical conductivity variation of Mukungwa observed in these three seasons was found to be in the range of accepted value (<1000 µS/cm). This indicated that Mukungwa water electrical conductivity was not changed by the rainy seasons analyzed. Thus there is no effect for aquatic life because it cannot cause osmotic problem for aquatic biota.

Turbidity of water is an important parameter, which influences the light penetration (̈oransson, Larson, & Bendz, 2013). Mukungwa turbidity trend in the three seasons analyzed was much greater than the standard value (5NTU) for surface water, where special variation was observed in 2017. This is due to presence of high sediments loads, brought by erosion in these three rainy seasons. Therefore the photosynthetic activity for aquatic plants (*e.g: algae*) have been adversely affected due to the lack of light penetration through water (REMA, 2010) even visiblity and oxygen penetration for Mukungwa aquatic animals.

Total suspended solids (TSS) built mostly of colloidal matters, which are not dissolved in water that can lead to anaerobic conditions for river water (REMA, 2010). According to the standard for surface water (<30mg/l), the change of total suspended solids in three rainy seasons analyzed for Mukungwa is very higher than the standard even it has been observed to increase in that period. So the solubility of oxygen was decreased and leading to anaerobic conditions for aquatic biota in Mukungwa River.

3.2.3 Nitrate-NO_3^- (mg/l)

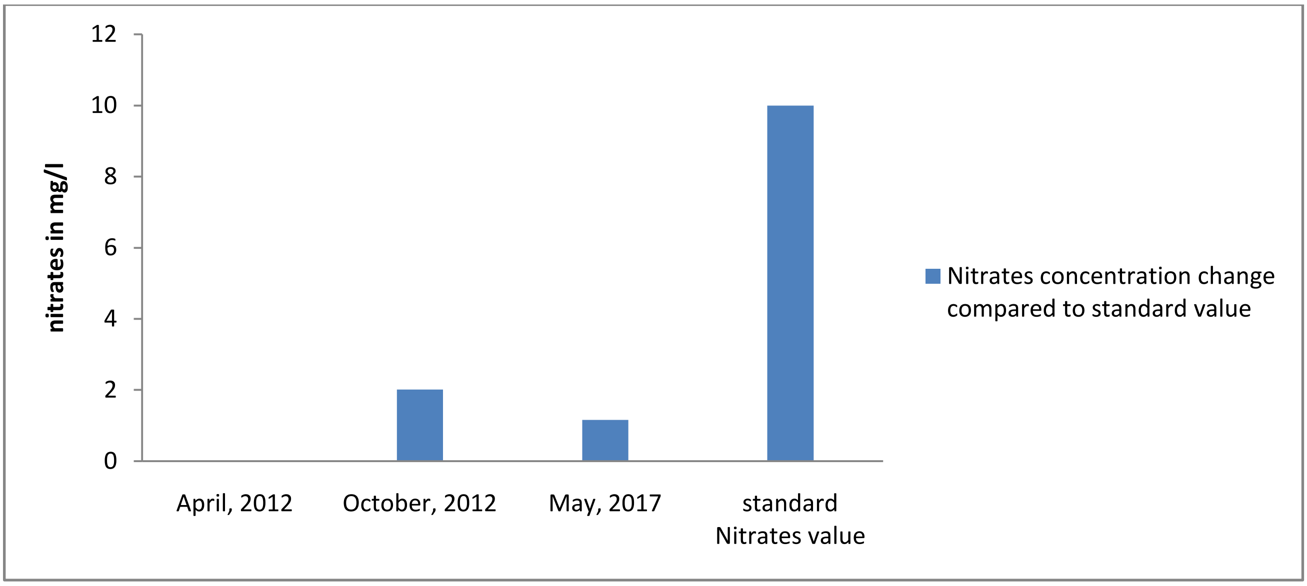


FIGURE 5. Variation of nitrates in MUKUNGWA River

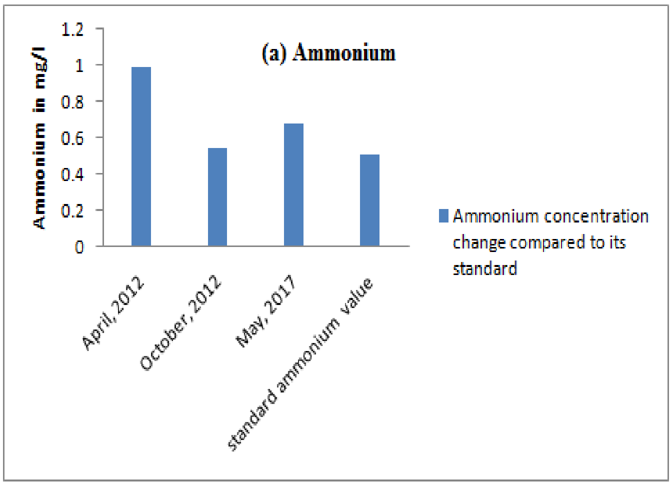
Nitrates are the most oxidized forms of nitrogen found in surface water and they are the end product of the aerobic decomposition of organic nitrogenous matter (Shah, 1988). The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial sources. The stimulation of plant growth by nitrates may result in eutrophication, especially due to algae. The subsequent death and decay of plants produces secondary pollution (Shah, 1988).

However, no nitrates were detected in April, 2012 in Mukungwa River because they may be absent or under detection limit of the machine that was used or they may have been in the form of nitrates. The nitrates were detected in October, 2012 and in May, 2017. This nitrates high concentration results from rice agriculture plantation around the river and nitrates recorded under the standard (<10mg/l) and it does not have effects on river water environment.

3.2.4 Ammonium and Phosphates (mg/l)

Excessive levels of ammoniacal nitrogen cause water-quality problems. Ammonia is the initial product of the decay of nitrogenous organic wastes, and its presence frequently indicates the presence of such wastes (Manahan, 2000). Ammonium (NH_4) is more readily used as a nitrogen source by algae and plants than nitrate (Manahan, 2000). The observed trend of

Ammonium (NH_4), is higher than the standard concentration (<0.5mg/l). The pollution by Ammonium in Mukungwa river observed may be caused by decaying of nitrogenous organic wastes and ammonium fertilizers brought by erosion.



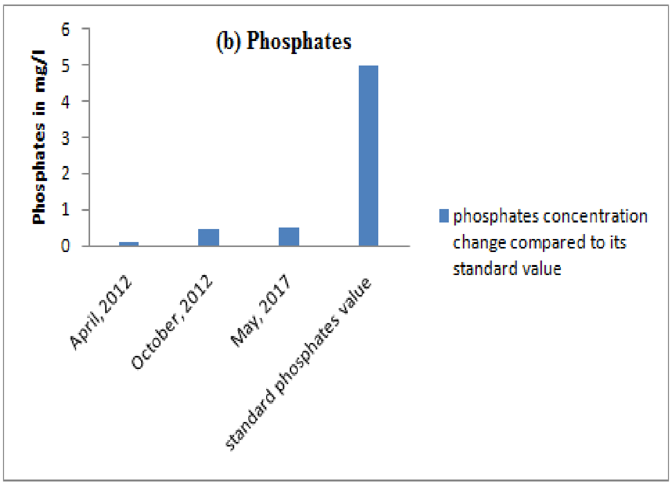


FIGURE 6. Variation of Ammonium (a) and phosphates (b) in MUKUNGWA river

Phosphates occur in natural or wastewaters as orthophosphates, condensed phosphates and naturally found phosphates. Their presence in water is due to detergents, used boiler waters, fertilizers and biological processes (Manahan, 2000). They are essential for the growth of organisms and a nutrient that limits the primary productivity of the water body. Inorganic phosphorus excess with potassium and nitrates cause algal blooms in aquatic ecosystems (REMA, 2010). Phosphates trend observed was very lower than its standard concentration (5mg/L) in Mukungwa. Thus, no pollution observed due to phosphates caused by erosion in the rainy season. Note that the concentration of phosphates was in increasing manner, may be in the future the pollution due to phosphates will be observed. Therefore, their sources must be monitored regularly to prevent their future pollution.

IV. CONCLUSION AND RECOMMENDATION

The study showed high variation of TSS (134mg/l, 178mg/l, and 582mg/l), turbidity (322NTU, 317NTU and 1560NTU) and ammonium (0.498mg/L, 0.536mg/L and 0.78mg/L), in three seasons analyzed compared to their world health organization standards on surface waters. Other parameters their seasonal changes were below standard values and present no concern about the protection of aquatic life. The quality of Mukungwa River needs prevention measures in order to control its pollution by erosion. This paper gives information on impact of rainy season on Mukungwa water quality to future researchers and decision makers to protect natural waters and regular monitoring of river waters in Rwanda.

Based on the above conclusions it can be recommended that:

The Rwandan government should take efforts for natural water resource monitoring each year in order to detect any new pollutant released in Rwanda water resources and to evaluate its source, hence take protective decisions.

As general observation, all contaminants originate from anthropogenic activities. It is in that regards that Rwandan population should be mobilized about water and sanitation measures in order to protect our water resources from pollution.

From field based observation, Mukungwa river basin is highly populated and mountainous affected by erosion which collects all materials from homes and bring them into river. So people around there should grow many trees to prevent erosion.

Mukungwa River is really contaminated by chemical pollution. People around the river, must be informed that the Mukungwa water is not safe for domestic uses except for irrigation.

Due to the data available and instrumentation, we have been limited to analyze other chemical parameters, but we recommend future researchers to expand parameters to be seasonally analyzed.

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